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Database of National Species List of Korea: the taxonomical systematics platform for managing scientific names of Korean native species

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A scientific name is one of changeable terms in biology whenever additional research results of specific taxa is accumulated. The Database of the National Species List of Korea (DBNKo) was developed to manage taxonomic information of Korean species, designed to describe the changeable and complex taxonomical structure and information. A Korean Taxonomical Serial Number (KTSN) was assigned to each taxon, different from the normally used systems that the scientific name was considered as primary key to manage higher rank of taxa systematically. Common names were also treated with the KTSN, reflecting that common name is considered as one type of taxon. Additional taxonomic information (e.g., synonyms, original names, and references) was also added to the database. A web interface with an intuitive dashboard presenting taxonomic hierarchical structure is provided to experts and/or managers of the DBNKo. Currently, several biological databases are available in the National Institute of Biological Resources (NIBR) such as a specimen database, a digital library, a genetic information system, and the shared species data based on the DBNKo. The DBNKo started sharing species information with other institutions such as the Nakdonggang National Institute of Biological Resources. It is an ideal centralized species database to manage standardized information of Korean species.

Keywords: centralized species database, Database of National Species List of Korea, DBNKo, Korean Taxonomical Serial Number, KTSN, web interface

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Introduction

A species is a basic unit for classifying all living creatures on Earth. Following the widespread adoption of binomial nomenclature by Carl Linnaeus (Linnaeus, 1753), the hierarchical taxonomic structure was established and has been continually improving (Stearn, 1959; Griffiths, 1976; Ereshefsky, 1997). With the development of information management technologies, a huge amount of species names had been deposited into these taxonomic databases. Several major species databases are now available; first, the Catalogue of Life (http://www.catalogueoflife.org/), which provides all available species names in the world with simple taxonomic information of genus, family, order, class, and kingdom (Roskov *et al*., 2013). It also provides both a web-based interface for searching species and an annual checklist. There are 1,837,565 species archived in this database, as well as 63,418 extinct species (As of June 2019). A second example is the Encyclopedia of Life (EoL; https://eol.org/; Wilson, 2003) which categorizes 1,999,030 species and higher taxa (NatureServe, 2008). Many researchers have contributed to this database, including high-quality taxonomic data of each species. A third example is the Global Biodiversity Information Facility (GBIF; https://www.gbif.org/), which provides species distribution data (1,393,178,066 occurrences; updated March 2020) and a comprehensive species list (3,499,326 accepted species and 2,148,205 synonyms; updated June 2019) (Secretariat, 2013). Yet another example is the National Center for Biotechnology Information (NCBI) taxonomy database (https://www.ncbi.nlm.nih.gov/tax-

onomy), which has been utilized as a standard database of species for many biological databases, such as the nucleotide database and genome database, managed by the US National Institute of Health (Federhen, 2011). The NCBI database frequently updates scientific names and higher taxa based on an internal review process with experts and mostly relies on molecular phylogeny data (Federhen, 2011). However, as its higher taxa classification has been subject to controversy, researchers usually used this taxonomy not as a main reference for their research. For instance, in plant species, many taxa have no assigned rank, e.g., higher taxa of *Dysphania pumilio* in NCBI is classed as Eukaryota (Superkingdom); Viridiplantae (Kingdom); Streptophyta (Phylum); Streptophytina (Subphylum); Embryophyta (no rank); Tracheophyta (no rank); Euphyllophyta (no rank); Spermatophyta (no rank); Magnoliopsida (no rank); Mesangiospermae (no rank); eudicotyledons (no rank); Gunneridae (no rank); Pentapetalae (no rank); Caryophyllales (Order); Chenopodiaceae (Family); Chenopodioideae (Subfamily); Dysphanieae (Tribe); *Dysphania* (Genus). On the other hand, the taxonomic information in the EoL (https://eol.org/; Wilson, 2003) includes more ranking for this species: Eukaryota (no rank); Archaeplastida (no rank); Chloroplastida (no rank); Streptophyta (no rank); Embryophytes (no rank); Tracheophyta (no rank); Spermatophytes (no rank); Angiosperms (no rank); Eudicots (no rank); Superasterids (no rank); Caryophyllales (Order); Amaranthaceae (Family); *Dysphania* (Genus). Furthermore, the two sources assign *D. pumilio* to different families: Chenopodiaceae was merged into Amaranthaceae based on molecular phylogenic result by Angiosperm Phylogeny Group (APG) (Chase *et al*., 2016), while another recent molecular phylogenic study (Hernández-Ledesma *et al*., 2015) and phylogenetic trees based on complete chloroplast genomes (Chen and Yang, 2018; Kim *et al*., 2019b; Kim *et al*., 2019a; Park and Kim, 2019; Kim *et al*., 2020), classed Chenopodiaceae as a separate family from Amaranthaceae. All of the aforementioned databases provide a web-based interface to access species information; however, most of these databases consist of a single search box for inputting the scientific name, limiting the results data with specific conditions for searching scientific names; for examples, finding synonyms under the specific genera or species.

Other species databases focus on specific taxonomic groups (e.g., plants, algaes, and fishes). The Plant List (http://www.theplantlist.org/) provides plant species names with valid name and synonyms (Kalwij, 2012). Synonyms are important information as they were used in the past and reflect taxonomic classification history. The International Plant Names Index (IPNI; http://www.ipni.org/) is another database for plant species (Ipni, 2015). The FishBase (http://www.fishbase.org/) database contains 34,300 fish species (As of March 2020), providing a web interface to search for scientific names (Froese and Pauly, 2009); and Algaebase (http://www.algaebase.org/) is a specialized database for algal species, covering 157,769 species (As of March 2020). All of these databases deal contain large species lists, which causes one critical limitation: some scientific names in these databases are neither recent or correct: for example, *Humulus japonicus*, a Korean plant species, is a valid name in the National Species List of Korea; however, The Plant List presents it as a synonym of *Humulus scandens*. This inconsistency among databases can significantly hinder species database construction. In essence, a species database equipped with a simple structure will categorize *H. japonicus* and *H. scandens* as different species, as the scientific name is used as a unique identifier. This leads to an increase in the number of species, although all these synonyms describe the same species. Because of this problem, localized species databases are required to validate scientific names by eliminating redundancies as much as possible. Furthermore, the complexities surrounding scientific names (e.g., synonyms) and user-friendly web-based interfaces should be considered to construct species database.

The Database of National Species List of Korea (DBNKo) of the National Institute of Biological Researches (NIBR; https://www.nibr.go.kr/) was built to manage scientific names of all Korean species, attempting to address the limitations of the previous databases. Higher taxonomical information, synonyms, and references of past taxonomic history were all included in the database design and the web-based interface. The DBNKo releases an updated species list annually, a high quality of species names was achieved by overcoming the limitations of previous databases. Moreover, the DBNKo is a centralized species database inside the NIBR system, providing standardized species data with higher taxonomical information to other systems managing biological information in the NIBR, acting as a model for other species systems.

Materials and Methods

Database structure of the DBNKo was designed to manage scientific names that can be more changeable than what computer engineers expected. The primary key for scientific name was defined to each taxon, termed as Korean Taxonomical Serial Number (KTSN), and then their hierarchical structure was implemented as parent-child relation in a table. In addition, we created several cache tables to retrieve species information efficiently and to synchronize species information with the other systems.

The DBNKo system was constructed based on an e-government framework (Sun *et al*., 2015) to achieve

high level of online security. The web interfaces for the DBNKo were developed using JSP and JAVA code with the Oracle database. JQuery was used to implement dynamic functions in the web interface to efficiently manage taxonomical information. An integrated authorization system was adopted from the mainframe of integrated authentication systems in NIBR to control permissions to access taxonomical data.

The tree interface of the DBNKo system was developed using the ztree plug-ins (http://www.treejs.cn/v3/main.php#_zTreeInfo), providing useful functions to manage the taxa stored in the database. A reporting tool was developed with native JAVA code generated the list of scientific names in Microsoft Word, Microsoft Excel, and Hangul Word Processor format files.

Results and Discussion

Korean Taxonomical Serial Number

The Korean Taxonomical Serial Number (KTSN) was defined as a unique, persistent, and non-intelligent number for taxa originating from Korean species names. Having unique KTSN values for individual species indicates a unique scientific name in the system. This is useful to track names of old taxa and their past synonyms, as our database will retain the relationships between the old and current species names. The non-intelligence aspect means that there is no specific meaning in the KTSN value except some rules: i) The first three digits indicate the classification of taxon names (120) or common names (121), and ii) taxa originating from different hierarchy, such as Category of Life (CoL) (Roskov *et al*., 2013) or Angiosperm Phylogeny Group IV (APG IV) (Chase *et al*., 2016) systems starts from 120000500001. The National List of Korean species was published in the last six years (Table 1), based on the DBNKo, indicating that this database has stabilized for Korean species by maintaining KTSNs.

Our database was also designed to manage Korean species considering higher taxonomic levels, such as family and order. These are very important as a summary of Korean species and understand their taxonomical distribution. Because of this, scientific names (genus + species) should have at least two KTSNs: one for the genus and another for the species. For example, *Platanthera mandarinorum* subsp. *ophrydioides* (KTSN: 120000065610), called Gu-reum-je-bi-ran in Korean (KTSN: 121000017509), consists of three KTSNs: i) that of *Plantanthera* (120000065603) called Je-bi-nan-cho-sok in Korean (KTSN: 121000035386); ii) that of *mandarinorum* (120000065607) called San-je-bi-ran in Korean (KTSN: 121000002449); and iii) that of *ophrydioides* (120000065610), called Gu-reum-je-bi-ran in Korean (KTSN: 121000017509). This would be tricky to organize and store in a standard data structure, such as an excel file; however, each taxon should be considered as an independent database record to manage hierarchical taxonomical structure. To avoid confusion from one species having several KTSNs, the representative KTSN for each species was defined as that of the lowest taxonomic rank of that species. Accordingly, the representative KTSNs for *Platanthera mandarinorum* and *Platanthera mandarinorum* subsp. *Ophrydioides* are 120000065607 and 120000065610, respectively. This prevents the system from assigning duplicated KTSNs to individual species.

Sometimes, genus and higher-ranking taxa change as new evidence emerges. For example, *Chenopodium* was separated into several genera: one of them is *Dysphania* genus that consists of 7 to 10 species (Aellen, 1930; Wilson *et al*., 1983) and some species including *Dysphania pumilio* were introduced in Korea (Chung *et al*., 2001). If *Chenopodium pumilio* (KTSN: 120000060667) used in the National Species List of Korea was to be changed to *D. pumilio*, two new KTSNs for *Dysphania* genus and *pumilio* species under *Dysphania* genus will be issued, and the resulting KTSN for *D. pumilio* would be different from that of *C. pumilio*. Consequently, *C. pumilio* will be treated as a synonym of *D. pumilio* in the DBNKo. All processes were recorded as historical alterations of taxonomic data, such as assigning new KTSNs and treating synonyms. These historical records track changing scientific names and the reasons for these changes. Moreover, scientific publications relating to such name changes are also registered in the database.

Common names, written in Korean and English, also

Table 1. Summary of Korean National Species Lists which have been published officially till now

Year published	# of taxa	Methods
2015	42,756	Excel files from each management taxonomical group.
2016	45,295	List was constructed based on Database of Korean National Species List
2017	47,003	List was constructed based on Database of Korean National Species List
2018	49,027	List was constructed based on Database of Korean National Species List
2019	50,827	List was constructed based on Database of Korean National Species List
2020	52,628	List was constructed based on Database of Korean National Species List

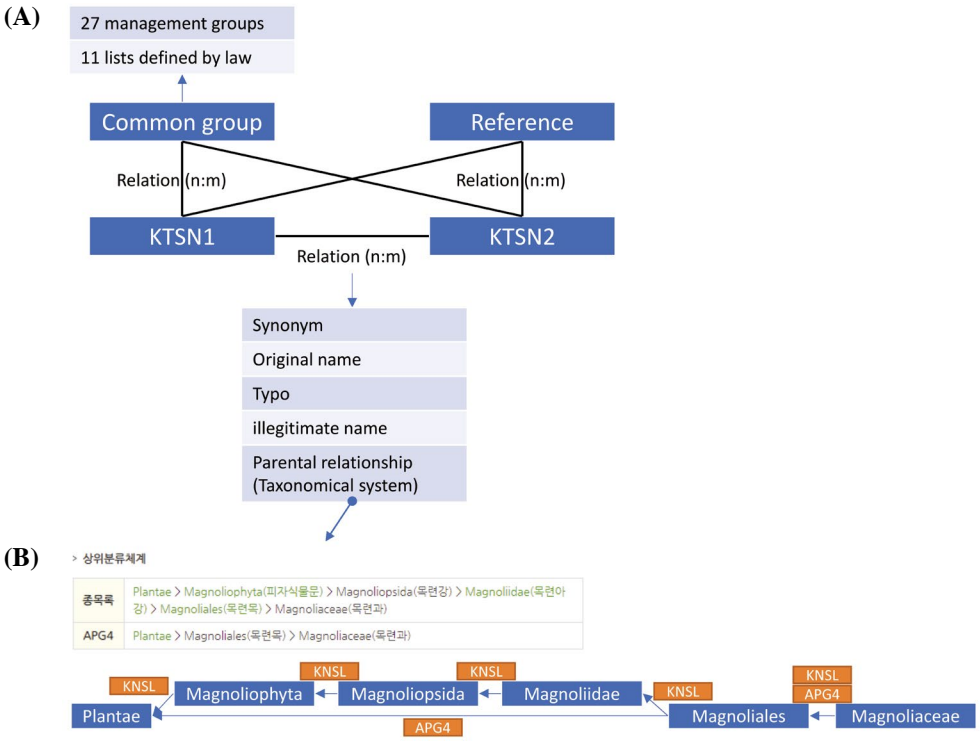

Fig. 1. Database structure of Database of Korean National Species List. (A) Presents relationship of major entities of the Database of Korean National Species List. Black thick lines are n:m relationship and blue arrows show detailed content types of each entity. (B) displays example of hierarchical relations of higher taxa originated from two different systems, KNSL and APG IV.

have a unique KTSN (those start with 121). It also contains local names and typos collected from diverse references such as books, reports, and records for traditional species information. Common names of species were included in the DNSL given how widely they are used to distinguish between individual species. However, there are instances where one common name refers to multiple taxonomic species or vice versa. To treat these cases, the relationship between the KTSN of scientific names and that of common names was maintained as many-to-many relationship. We are also planning to expand to local names and common names in other languages, making the database more useful to find diverse common names of taxa.

The KTSN for taxa start with 120000000001; while those for common names start with 121000000001, enabling users to easily distinguish them from one another. Based on the current status of species stored in the database, additional taxa from the other government institutes, such as the Ministry of Science, ICT and Future Planning, will be integrated into the database.

Taxonomic data structure in the DBNKo

The DBNKo was designed to cover complex layers of taxonomic information including the taxon itself, the relationships between valid names and synonym, hierarchical structure (the parental relationship between KTSNs) with taxonomical systems, and related references (Fig. 1A). It covers multiple hierarchical systems, such as the CoL (Roskov *et al*., 2013) and APG IV (Chase *et al*., 2016), which is plant-specific. Some taxa can be identical in both hierarchical taxonomic systems: for example, the Magnoliaceae family (KTSN: 120000060031) exists both in the National Species List of Korea and in the APG IV; it has therefore been assigned a shared parental KTSN (Order Magnoliales, KTSN: 120000060030) and two different next parental KTSNs: one for Class Magnoliopsida (KTSN: 120000060028) in the National Species List of Korea and the other one is Kingdom Plantae (KTSN: 120000098391; Fig. 1B). This way to store multiple hierarchical taxonomic information will be efficiently used to compare the hierarchical structure for different taxonomical systems to improve the National Species List of Korea.

To maintain the database containing these complex taxonomical data with keeping taxonomical content up-to-date for researchers, generally, databases for dealing with species information provide web interfaces for managing species name, taxonomical structure (Fig. 2A), and common names together with synonyms (Fig. 2B). Additionally, different properties of categorized species

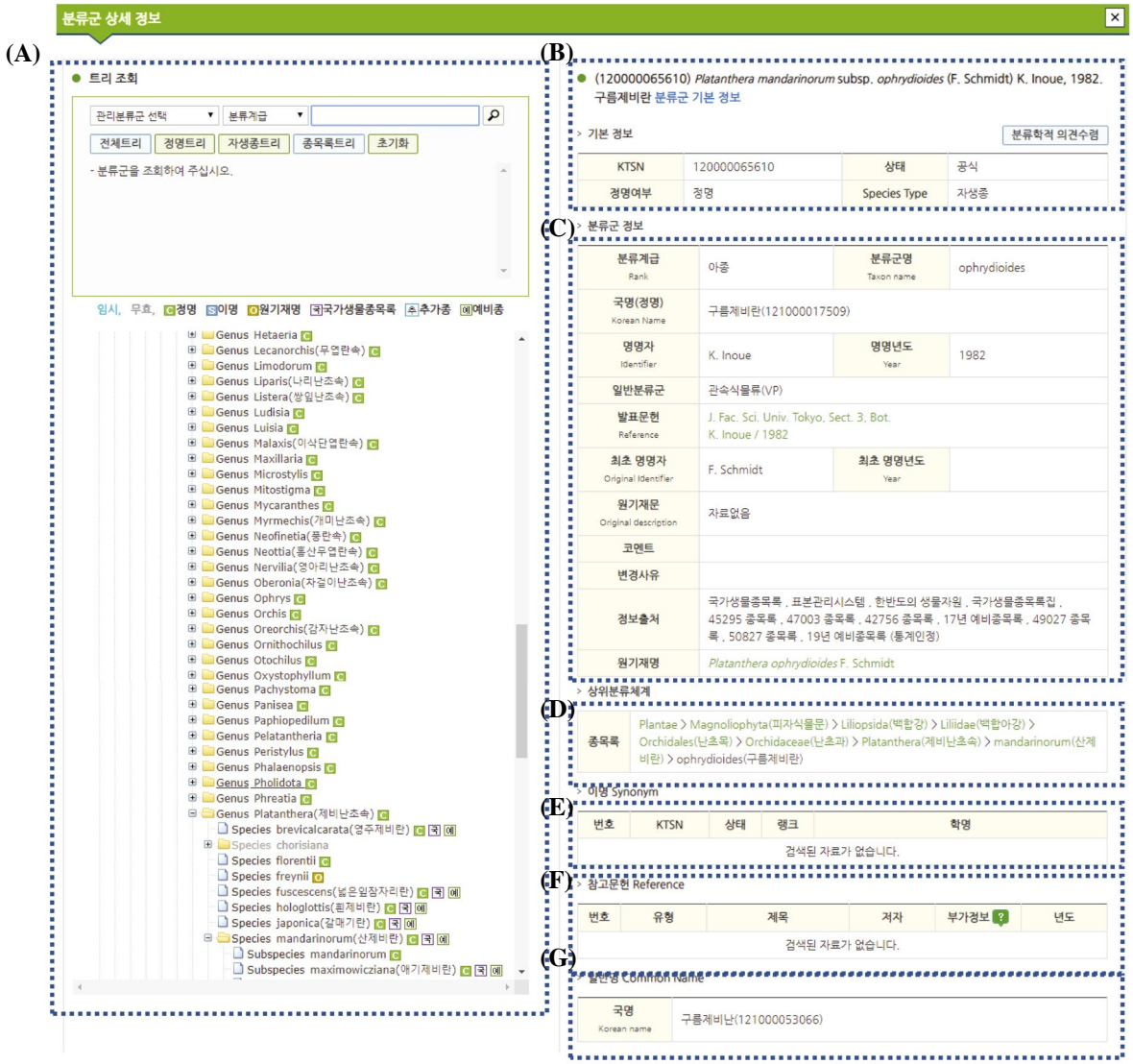

Fig. 2. Web interface of taxon in Database of Korean National Species List. (A) Provides hierarchical structure of taxon with the tree interface. (B) shows basic information of taxon including KTSN, species properties, representative common names, and status of KTSN. (C) displays ranks, names, common names, identifiers, origins and etc. (D) displays information higher taxa based on hierarchical systems. (E) shows the list of synonyms. (F) is the list of references related to this taxon. (G) is the list of all common names except representative name.

(i.e., naturalized species, candidate new species, foreign species, and candidate new foreign species) are also managed in the database (Fig. 2B). Moreover, synonyms and original names of the species, important information for taxonomists, is also stored in the DBNKo (Fig. 2B). Detailed taxonomic information is displayed in the middle section (Fig. 2C). Furthermore, hierarchical structures of the taxon originated from multiple hierarchical systems are displayed, if available (Fig. 2D), which is the same as Fig. 1B. With synonyms and original names, identifiers, identifier year (Fig. 2E), and references are also included in the database (Fig. 2F). Common names in the database are classified as representative names, majorly used by people and the remaining common names including local names (Fig. 2G).

To determine the sources of species names stored in the database, which are major systems managed in the NIBR, they were also included as the origin of species in our database. In addition, the National Species List of Korea has been updated annually, this origin covers species list of each year to show which species names were included in each year (Fig. 2C).

Since the current National Species List of Korea covers known species ranging from bacteria to mammals, a strategy for classifying species names as group is strongly required in the aspect of management species name

Table 2. List of species lists defined by laws managed in Database of Korean National Species List

Name (Korean)	Code	Last updated date	# of taxa
멸종위기 야생생물	EXT	2017-12-29	267
먹는 것이 금지되는 야생동물	DNE	2012-07-27	31
포획·채취 등의 금지 야생생물	DNC	2015-03-25	464
수출·수입등 허가대상 야생생물	EIA	2015-03-25	418
인공증식 또는 재배를 위한 포획·채취 등의 허가대상 야생생물	PRO	2015-03-25	12
국외반출 승인대상 생물자원	EA		3,751
생태계교란 생물	ED		19
위해우려종	HC		4
한국의고유생물	ES		2,302
국가기후변화지표생물	CI		100
획득 신고대상 생물자원	ACQUIRE		3,751

by experts whose major are different. Currently, there are 27 defined management groups considering taxonomical classification (Fig. 2C), with 26 of those including species (Table 3) One group which is recently defined, Cephalochordate, does not have Korean species at this moment. Administrators for each group as taxonomical experts were assigned to efficiently manage species data. Their roles are i) collecting newly identified species in Korea in each group, ii) approving species names registered by researchers with proper references, and iii) managing previously constructed taxonomical hierarchy.

Legal species lists managed in the DBNKo

The DBNKo includes several species lists defined under a legal framework, such as species that are almost extinct in Korea and species lists for international trade (Table 2). These lists were composed from various legal documents; they sometimes contain different scientific names than the current valid names due to errors made either in the drafting of these documents or because of time differences and changing denominations since their publication. These problems can be solved by registering them into the DBNKo once and linking them to the currently valid name in the most recent National Species List of Korea (Table 1). To overcome the problem that changing species list updated annually requires updating species name based on recent National Species List of Korea, the DBNKo provides the pipeline to map these lists against the most recent announced annual species list of Korean species. The first step of this mapping process is finding a valid species name in the DBNKo. For some species of insects and invertebrates (e.g., *Camponotus* (*Colobopsis*) *nipponicus* and *Cumella* (*Cumella*) *alveata*) of insects and invertebrates) it is more difficult to find the correct species name because of discrepancies in subgenera names. As the subgenus rank is usually used to classify species under a specific genus in more detail, it tends to be more flexible than at the genus level (e.g. molecular phylogeny study can change the previous classification of subgenera level (Hong *et al*., 2017)). In this step, the subgenus is considered an additional taxon, resulting in a significantly higher mapping rate without considering subgenus than that with subgenus name. The second step is to include Korean names when the scientific name could not be mapped to those in the National Species List of Korea because of limited coverage of the National Species List of Korea. Once species name of which Korean name is the same as the National Species List of Korea is found, the pipeline will suggest this result to the expert for verification. The third step and most important step is to update these lists with every annual publication of the National Species List of Korea announced by NIBR, including synonyms and additional relations (e.g., typographic errors) to the valid name. The above process enables the species lists managed in DBNKo to be systematically up to date.

Web interfaces to manage hierarchical data structures

The DBNKo contains data on each taxon, presented in a tree structure (Fig. 3). To provide a user-friendly data visualization output on the web interface, a tree-based interface was designed and implemented. Each node in the tree indicates a taxon with a unique KTSN (Fig. 3). If the rank of the taxon is species or lower these nodes are aggregated with those of species levels, according to the National Species List of Korea. Once users want to move to neighbor species or genus, they can click on specific nodes to see the detailed information (Fig. 3B, blue arrow) or click the plus icon to open the list of taxa under it to access the raw data (Fig. 3B, orange arrow).

The search function above the tree interface was im-

Table 3. Twenty-six management groups of the Database of Korean National Species List

English name	Korean name	Code	# of taxa
Mammalian	포유류	MM	125
Avian	조류	AV	527
Reptile	파충류	RP	32
Amphibian	양서류	AM	21
Fish	어류	-P	1,294
Urochordata	미삭동물류	UC	128
Invertebrate	무척추동물류 (곤충류제외)	IV	9,900
Insect	곤충류	IN	18,638
Vascular Plants	관속식물류	VP	4,576
Bryophytes	선태류	MS	941
Charophyta	윤조류	CR	956
Chlorophyta	녹조류	CL	812
Rhodophyta	홍조류	RD	641
Diatoms	돌말류	DI	2,174
Cryptophyta	은편모조류	CT	15
Haptophyta	착편모조류	HT	7
Dinophyta	와편모조류	DN	442
Pyrrhophyta	황적조류	PY	2
Ochrophyta	대롱편모조류	OR	378
Fungi	균류	FG	4,288
Lichen	지의류	LC	1,133
Protozoa	원생동물류	PR	2,018
Euglenophyta	유글레나조류	EG	354
Cyanobacteria	남조류	CY	377
Bacteria	세균류	BA	2,821
Archaea	고세균류	AR	18
Total			52,628

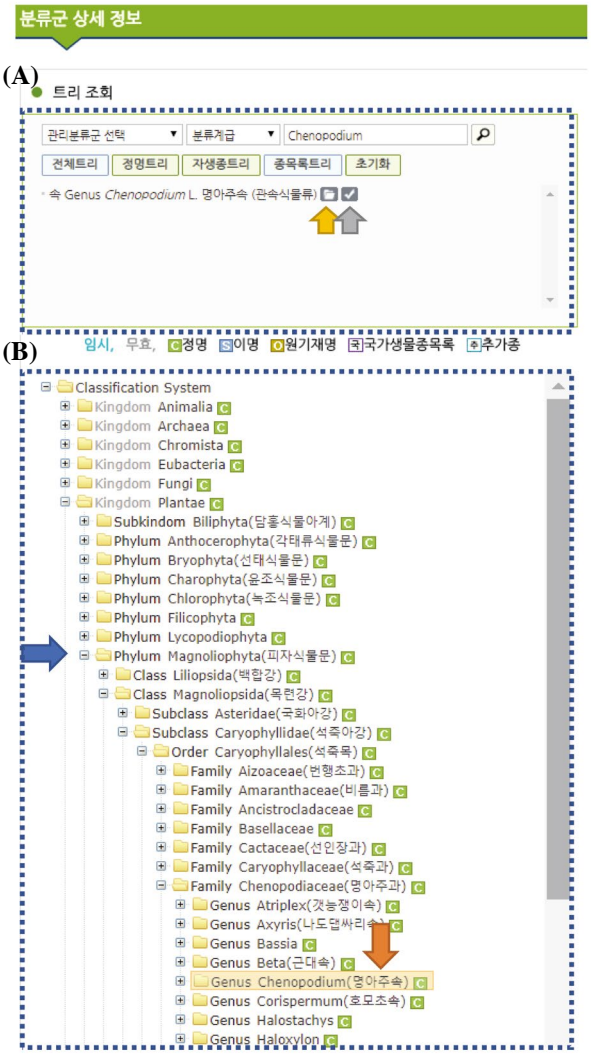

Fig. 3. Tree interface of taxon. (A) Shows interface to search by management groups, rank, and name. Yellow arrow indicates folder icon which open all higher nodes of the taxon up and grey arrow shows check icon which provides detailed information of the taxon. (B) displays tree interface for hierarchical structure of taxa. Plus icon indicated by blue arrow means open the lower taxa in the specific taxon, and each node (orange arrow) represents each taxon.

plemented to directly find specific taxa (Fig. 3A). In the search results, the name of taxa and two icons (Fig. 3A, yellow and grey arrows) were displayed. The folder icon (Fig. 3A, yellow arrow) provides a function to open higher nodes of the taxon up, while the check icon (Fig. 3A, grey arrow) provides detailed information of the taxon in the right section of the screen (Fig. 2B-G).

The DBNKo also provides a search interface with various options to manage taxa efficiently (Fig. 4A), reflecting the complexity of the taxonomic data in the database. After inputting the search terms on the interface, a list of taxa can be obtained, displaying the status, management group, KTSN number, rank, name, identifiers, identified year, common name, and origin of the searched taxon (Fig. 4B). By clicking on the KTSN number of each taxon, the user can see a brief information in the extended layer under it (Fig. 4C) describing its hierarchical structure. There are more interfaces to show higher taxon and to print report forms for the search terms. Additionally, there is a download function of the species list to export data.

The species list with additional information, including higher taxonomy, common names, and the date of their introduction into the National Species List of Korea (Fig. 5), are provided in the website of the platform for biodiversity in Korea (http://www.kbr.go.kr/; Fig. 6). Users can access the list by clicking the button located in the upper right corner (i.e., the dotted box in Fig. 5) prompting the download of an excel spreadsheet. The official



Fig. 4. Web interface of list of taxa with search options. (A) Displays complex interface for searching taxon. (B) is the list view of taxa searched. (C) shows the example of brief information of taxon which will be appeared by clicking KTSN number in the list view.

species lists is updated annually.

Web interfaces to manage additional information of the National Species List of Korea

The current DBNKo includes additional information, such as special lists of species defined by law, common names, and references. Web interfaces to manage lists of species defined by law provide two main functions: i) management of types of special species list defined by law (Fig. 7) and ii) management of species list in each type of special list defined by law. As we expect new species to be added to these special lists in the future, the administrator can add new types of special species list via the first function, management of special species list types. Currently, 15 lists are managed under the DBNKo (Fig. 7). In each list, an administrator can search species by KTSN, scientific name, and taxon name (Fig. 8A) then register the Korean names and any other additional information (e.g., Red List status) defined in the law (Fig. 8B).

Korean names are defined as common names in the DBNKo; they can thus be managed through the function that normally manages common names (Fig. 9). The DBNKo maintains independent KTSNs for common names so administrators can add new common names through this menu. However, this concept is relatively complex to taxonomists because it is not a one-to-one relationship, which is easy to understand, so that most of the management functions of common names are in the taxon management menu, where an administrator can register or update common names (Fig. 2G).

References can be altered under the reference management menu, including registering new references and assigning references to specific taxa (Figs. 10A and 9B). New references can be registered or existing ones can be modified (Fig. 10A). Additionally, the assignment link (the dotted box in Fig. 10A) provides a web interface to assign specific references to multiple taxa at one time (Fig. 10B).

To make the species lists for reports or publications, the DBNKo also provides a function to generate reports based on selected taxa (Fig. 11). Users can select and place taxa into a basket and select options to generate species lists (Fig. 11A). As the generation of species lists can take a relatively long time, the task will be registered and users can check its status periodically (Fig. 11B). After finishing this task, three files will be ready for download:



Fig. 5. Introduction page of Korean National Species List. Introduction page of National Species List of Korea in the platform for biodiversity in Korea (http://www.kbr.go.kr/content/view.do?menuKey = 446&contentKey = 14).



Fig. 6. Download page of Korean National Species List. This web page provides the download link of National Species List of Korea in the main page of the platform for biodiversity in Korea (http://www.kbr.go.kr/).



Fig. 7. Web page of list of special list of species defined by law. This web page provides management function of special list of species defined by law.

a Hangul file, as well as Microsoft Word and Excel files (Fig. 11C).

The DBNKo as a centralized species database in NIBR

Species information is fundamental information for biological resources, such as specimens, dry samples, and DNA samples. The NIBR manages several important biological databases, such as the specimen database and Wildlife Integrated Genetic Information System (WIGIS). These databases contain their own tables of species names in the early phase; after the stabilization of the DBNKo, they started referring to species information stored in the DBNKo. This indicates that species names in this database were enough to be considered as



Fig. 8. Web pages of management function of special list of species defined by law. (A) Presents the web interface of searching taxon with five functions. (B) shows the list of registered species defined by law with Korean name.



Fig. 9. Web page of management of common names in Database of Korean National Species List. This web page displays the list of common names registered in the database.

a standardized species list. Now, almost every system managed by the NIBR uses the KTSN to extract standardized species information (Fig. 12). Moreover, other databases managed by government institutes including Nakdonggang National Institute of Biological Resources now obtains their species data from the DBNKo (Fig. 12). Other institutes such as the National Institute of Ecology are in the process of joining our species database to share KTSN data as a standardized species information. Once the technical process is established and stabilized, the DBNKo will be a centralized species database in Korea.

Future Directions

In recent years, a centralized database (named as Da-

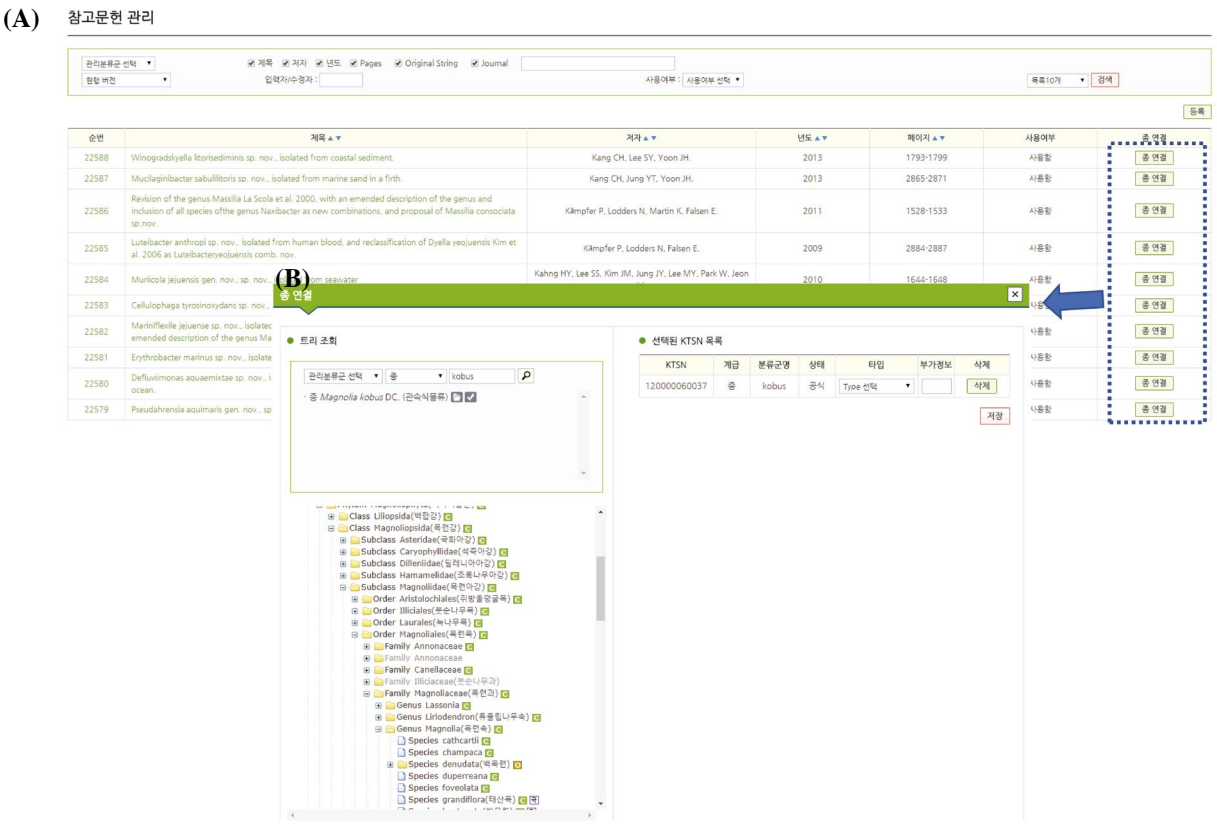

Fig. 10. Web pages of management of references in Database of Korean National Species List. (A) Shows the list of references with function to assign references to taxa. (B) Web interface of function assigning reference to taxa.

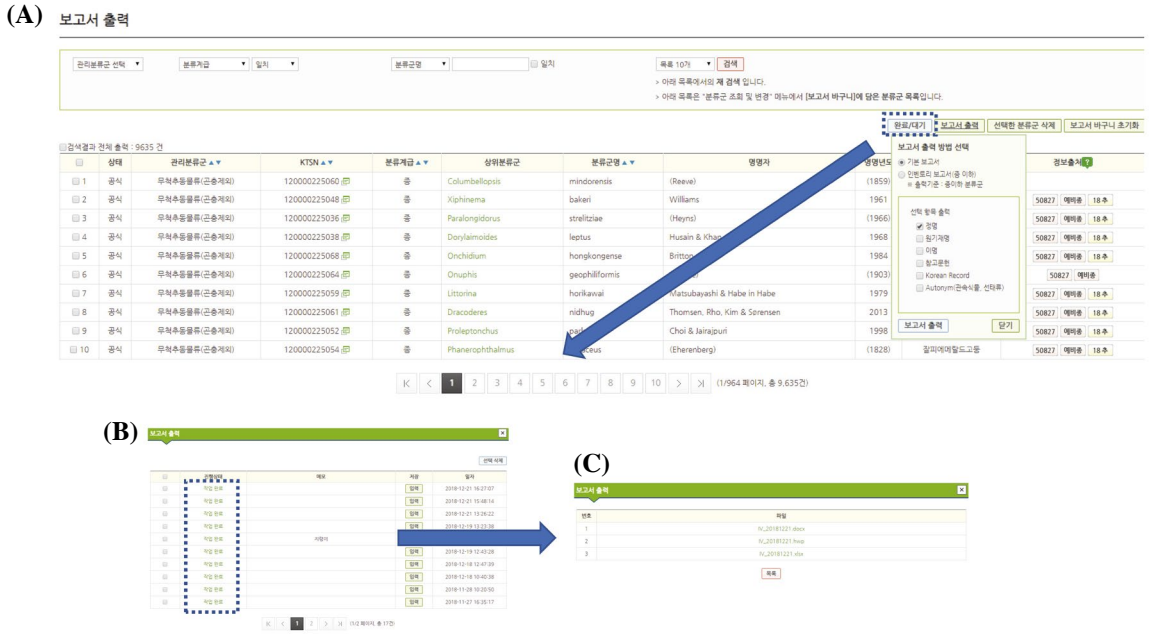

Fig. 11. Web interface of reporting tools in Database of Korean National Species List. (A) Presents the basket of report. Dotted box presents option of generating reports. (B) shows the list of tasks registered for generating report. (C) displays three different formats of report generated by the Database of National Species List of Korea.

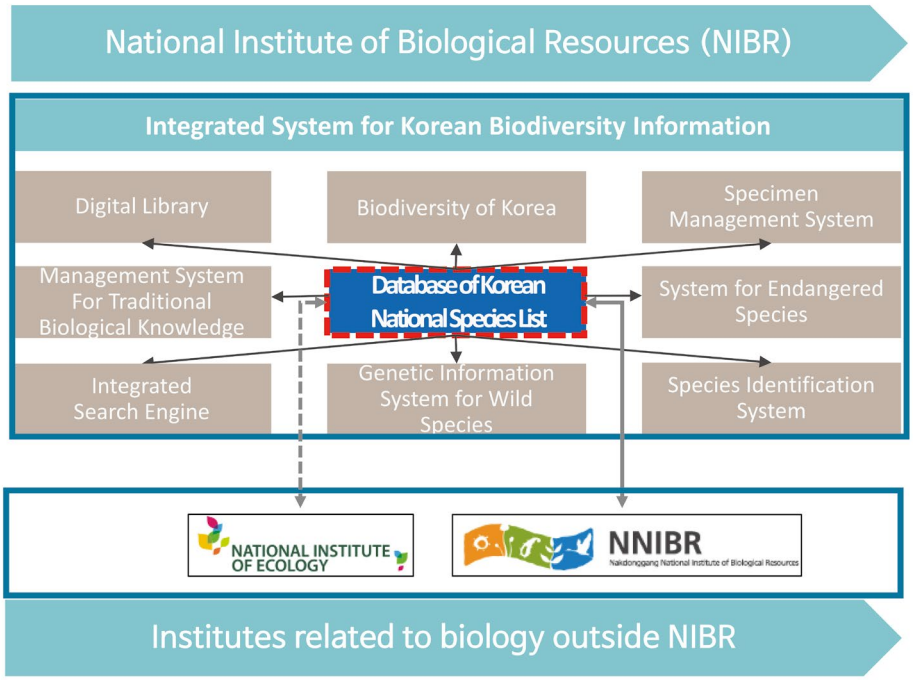

Fig. 12. System structure of Database of Korean National Species List. Grey rectangles represent systems related to the Database of National Species List of Korea and blue rectangles indicates systems using species information via Database of National Species List of Korea outside of NIBR. Black arrows indicate utilization of taxonomic information from the Database of National Species List of Korea and Grey arrows present communication with institutes outside of NIBR. Dotted grey arrow means commination channel will be established soon.

tabase of National Species List of Korea; DBNKo) has been created, collating data from the annual publication of the National Species List of Korea, using the KTSN as a unique identifier. Names of all Korean species are managed inside the database with the web interfaces described in this paper. Given the complexity of the taxonomic information needing to be included, additional information not mentioned in this paper is also managed in the DBNKo: for instance, the Korean Red List of Endangered Species was synchronized with species database using the KTSNs.

There is more than one system to classify species at higher taxonomic levels. For example, there are two classical taxonomical systems of flowering plants, Cronquist (Cronquist, 1965) and Engler (Garten, 1886), which provide different higher taxonomical structures of flowering plants. For example, order Helobiae used in the Engler system does not exist in Cronquist, instead, orders Alismatales, Hydrocharitales, and Najadales in the Cronquiest system covers families of order Helobiae. Additionally, an APG IV system (Chase *et al*., 2016) constructed from the results of molecular phylogenic studies in plants adopts different genus names for sample species. This problem exists in most management groups, making it difficult to obtain the correct species name. Soon, the DBNKo will be equipped with adequate web-based tools and additional database structure to maintain multiple hierarchical structures of the taxa stored in the database, which will be helpful to every user including researchers via providing multiple hierarchical taxonomic structure.

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References

Aellen, P. 1930. Die wolladventiven Chenopodien Europas.

Chase, M.W., M. Christenhusz, M. Fay, J. Byng, W.S. Judd, D. Soltis, D. Mabberley, A. Sennikov, P.S. Soltis and P.F. Stevens. 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society 181(1):1-20.

Chen, Y. and Z. Yang. 2018. Characterization of the complete plastome of *Dysphania botrys*, a candidate plant for

cancer treatment. Mitochondrial DNA Part B 3(2):1214-1215.

Chung, Y., C. Lee, W. Paik, J. Ahn and A. Park. 2001. Taxonomical investigation of the goosefoot (Genus Chenopodium; Chenopodiaceae) in Korea on a basis of external morphological characters. Kor J Weed Sci. 21:229-235.

Cronquist, A. 1965. The status of the general system of classification of flowering plants. Annals of the Missouri Botanical Garden 52(3):281-303.

Ereshefsky, M. 1997. The evolution of the Linnaean hierarchy. Biology and Philosophy 12(4):493-519.

Federhen, S. 2011. The NCBI taxonomy database. Nucleic Acids Research 40(D1):D136-D143.

Froese R, Pauly D. 2009. FishBase.

Garten, B.B. 1886. Führer durch den Königlich botanischen Garten der Universität zu Breslau. JU Kerns Verlag (Max Müller).

Griffiths, G.C. 1976. The future of Linnaean nomenclature. Systematic Zoology 25(2):168-173.

Hernández-Ledesma, P., W.G. Berendsohn, T. Borsch, S. Von Mering, H. Akhani, S. Arias, I. Castañeda-Noa, U. Eggli, R. Eriksson and H. Flores-Olvera. 2015. A taxonomic backbone for the global synthesis of species diversity in the angiosperm order Caryophyllales. Willdenowia. pp. 281-383.

Hong, Y., Y. Luo, Q. Gao, C. Ren, Q. Yuan and Q.-E. Yang. 2017. Phylogeny and reclassification of *Aconitum* subgenus Lycoctonum (Ranunculaceae). PLoS One. 12(1).

Ipni. 2015. The international plant names index. The Royal Botanic Gardens Kew.

Kalwij, J.M. 2012. Review of 'The Plant List, a working list of all plant species'. Journal of Vegetation Science 23(5):998-1002.

Kim, Y., J. Park and Y. Chung. 2019a. Comparative Analysis of Chloroplast Genome of *Dysphania ambrosioides* (L.) Mosyakin & Clemants Understanding Phylogenetic Relationship in Genus *Dysphania* R. Br. Korean J. Plant Res. 32(6):644-668.

Kim, Y., Y. Chung and J. Park. 2019b. The complete chloroplast genome sequence of *Dysphania pumilio* (R. Br.) Mosyakin & Clemants(Amaranthaceae). Mitochondrial DNA Part B 4(1):403-404.

Kim, Y., Y. Chung and J. Park. 2020. The complete chloroplast genome of *Oxybasis glauca* (L.) S. Fuentes, Uotila & Borsch(Amaranthaceae) as the first chloroplast genome in genus Oxybasis. Mitochondrial DNA Part B 5(2): 1410-1412.

Linnaeus, C. 1753. Binomial nomenclature and hierarchical classification system. Species Plantarum.

NatureServe, F. 2008. NatureServe Explorer: an online encyclopedia of life. NatureServe Arlington, Virginia.

Park, J. and Y. Kim. 2019. The second complete chloroplast genome of *Dysphania pumilio* (R. Br.) mosyakin & clemants(Amranthaceae): intraspecies variation of invasive weeds. Mitochondrial DNA Part B 4(1):1428-1429.

Roskov, Y., T. Kunze, L. Paglinawan, T. Orrell, D. Nicolson, A. Culham, N. Bailly, P. Kirk, T. Bourgoin and G. Baillargeon. 2013. Species 2000 & ITIS Catalogue of Life, 2013 Annual Checklist.

Secretariat, G. 2013. GBIF Backbone Taxonomy. Global Biodiversity Information Facility, http://www gbif org/species/2879175.

Stearn, W.T. 1959. The background of Linnaeus's contributions to the nomenclature and methods of systematic biology. Systematic Zoology 8(1):4-22.

Sun, P.L., C.Y. Ku and D.H. Shih. 2015. An implementation framework for E-Government 2.0. Telematics and Informatics 32(3):504-520.

Wilson, H.D., S.C. Barber and T. Walters. 1983. Loss of duplicate gene expression in tetraploid Chenopodium. Biochemical Systematics and Ecology 11(1):7-13.

Wilson, E.O. 2003. The encyclopedia of life. Trends in Ecology & Evolution 18(2):77-80.

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